e Center for Marine Coastal Studies – North Carolina State University.

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NORTH CAROLINA STATE UNIVERSITY
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Introduction

Storm erosion of beaches and dunes of the North Carolina coast has always occurred, but it has not been a serious economic problem until recently when increased development of beach front property has taken place. In some locations, structures have been built seaward of the beach storm recession line and have sustained considerable damage. This report presents the results of a study to determine the expected storm induced beach erosion which can provide preliminary information needed for coastal land management.

Preliminary beach development limits recommended in this report are based on calculated recessions of beaches for storm occurrences of one in twenty five, one in fifty, and one in a hundred year frequencies. Necessary field data were collected from fishing piers along the entire North Carolina coast except for Currituck and Hyde Counties where no piers exist. Beach recession values were calculated using essentially a semi-empirical procedure that is a modification of a technique adapted by Vallianos of the Wilmington District of the U. S. Corps of Engineers from work done earlier by Edelman (1).

Procedure

The general method employed in this study to predict storm induced beach recession involves the balancing of the areas of upland erosion and offshore deposition due to a storm. It is assumed, therefore, that all sand eroded by the storm is deposited directly offshore or that it is moved along the shore at a steady rate; as much is coming into the area up-current as is leaving down-current. Based on field observations and model study tests (2,3) it has been determined that the offshore profile flattens by a factor of about two from its prestorm slope. The sand required for this flattening comes from the beach and dunes.

Beach profiles needed for this study were obtained, as noted earlier, from fishing piers along almost the entire North Carolina coast. Soundings (the distance from the beach and offshore bottom to the top of the pier) were made at closely spaced intervals, but away from the pier pillings to avoid making measurements in scour holes. Most piers were near enough to a U. S. Coast and Geodetic Survey bench-mark so that these soundings could be converted to beach profiles based on mean sea level (MSL). In those locations where established bench marks were not available, assumed elevation relative to the waterline was used. Using the time that the waterline soundings were made, elevations were converted to an estimated MSL using N.O.A.A. tide tables (4) applicable to the pier location.

The height, width and shape of the dunes at each pier location were recorded and in those locations where man-made structures changed the shore profiles, measurements of dunes characteristic of the area were used.

Storm surge levels above MSL as a function of storm return frequency were obtained (5,6,7,8,9) for the five areas of North Carolina and are shown in Figure 1 and listed in Table 1. The storm surge level is defined as the still water height that can be expected to occur once during the indicated return frequency. For the purposes of this study surge levels for storms with a once in twenty-five, fifty and one-hundred year probability of reoccurrence were used to obtain a range of beach recession values. These surge levels (S) were used to obtain the height (H) and breaking depth (H_b) of the waves associated with the storm. They were then used to calculate the associated beach recession using the modified technique of Edelman discussed in detail in the remainder of this section.

The technique (see Figure 2 for example calculation) involves plotting the before-storm beach profile and a line representing the storm surge level (S). For each of the three storm reoccurrences wave height (H) is calculated by

$$H = 1.5(S), \tag{1}$$

and the breaking depth of the wave (H_b) above the bottom is given by

$$H_b = 1.3(H). \tag{2}$$

To find the breaking depth relative to MSL (H_m), the storm surge is subtracted from H_b, i.e.,

$$H_m = H_b - S. \tag{3}$$

Values of H_m for this study are shown in Table 1. The outer limit of sand deposition is assumed to occur at a depth approximately equal to the breaking depth of the wave. The foreshore limit of offshore bottom slope or beach breakpoint in the before-storm profile is then found. An examination of all the profiles obtained by this study where the foreshore was clearly discernible, indicated that the breakpoint occurred at a mean depth of approximately -1.5 ft. below MSL, and a horizontal line at this depth was then drawn and acted as the pivot line along which the storm-beach profile slope changed.

Except at the two extreme ends of the storm profile, the beach and offshore slopes were flattened by a ratio of 2.1:1 compared to the original profile. As discussed earlier this flattening was determined from model study tests for storm waves. In constructing the storm-beach profile from a pre-storm multi-sloped beach, it was necessary to establish a procedure for selecting the locations at which the storm profile would change. Landward of and including the breakpoint pivot line, all storm-beach slopes change at a 2.1 to 1 ratio on a line drawn vertically from the point where the pre-storm profile changes slope, as shown in Figure 2.

The dune characteristics that were measured during this study may be classified in three ways. First, the dune will be sufficiently high and wide to remain above the storm surge level during the erosion process. Secondly, the top of the dune will be above the storm surge initially, but will be below the storm surge as erosion of the dune progresses, and thirdly, the dune will be below the storm surge level initially so that the dune will be overtopped throughout the entire erosion process.

For the first classification the 2.1:1 storm profile line will intersect storm surge level below the top, and a 10(V):1(H) slope is drawn from this intersection to the top of the dune. Under the second and third classifications the storm profile will not intersect storm surge level so the storm profile retains its 2.1:1 ratio of the original until it intersects the back side of the dune.

Finally, to determine the storm-beach profile it was necessary to match the area of erosion with the area of deposition as shown in Figure 2. A planimeter was used to measure areas and the storm profile lines were adjusted until the erosion and deposition areas were equal.

For the second and third conditions it is apparent that with overtopping of the dune not all sand eroded by the storm will be deposited offshore, as assumed by this procedure and more erosion will actually occur than is predicted by this technique. This additional erosion at overwash areas has not been considered in the calculations. Finally, a measure of the recession of the beach due to the storm from a relatively fixed and identifiable point was made. The measurement of the extent of storm damage was taken as the distance from the seaward toe of the dune to the landward point at which the storm profile crossed the original profile. The recession values for each pier location are shown in Table 2. The measurements from the toe of the dune were chosen to express the range of recession for the reoccurring storms, because this point was judged to be the most stable and most easily identified.

Results and Discussion

The calculated storm recessions for each of the 29 piers that were analysed are presented in Table 2. This table not only indicates the amount of anticipated recession but presents information on the dune characteristics in the area. The calculated values of storm erosion depend on several factors; first, the storm surge level that can be expected for the various reoccurrence frequencies, secondly, the height and massiveness of the dune at each location and thirdly, the distance of the dune from the mean water line. The affects of these factors can readily be noted in the data presented in Table 2.

From the results of Table 2 recommended ranges of recession lines along the North Carolina coast are presented in Table 3 and in Figures 3 and 4 for reoccurrance frequencies of one in twenty five years and one in a hundred years. These recommended ranges were obtained by weighting the various data according to the degree of reliability that could be assumed for each of the individual pier locations. Thus, for pier locations where the elevations were obtained from estimates of the water level obtained from N.O.A.A. tide tables, less weight was given to the results than for those which were obtained from U.S.G.S. bench-marks. At several of the pier locations there were sea walls constructed and in those areas no adjustment was made for the difference in erosion affect at the sea wall. Also, the toe of the dune at three locations was unidentifiable or was found to be below or very near the mean high water level.

Although the ranges presented in Table 3 are based on a semi-empirical method and are somewhat preliminary, they represent a reasonable estimate of storm induced beach erosion limits. They are recommended for use in coastal zone management as preliminary criteria for establishing a dynamic zone.

The above results must be considered preliminary since the present profiles were only taken where piers exist and then only at a single time during the summer. Additional precision could obviously be obtained by securing additional profiles during other times in the year. In addition, in areas where piers are not located, profiles should be obtained by soundings from a boat.

The storm induced recession prediction presented in this report is considered to be useful for determining the distance from the toe of the primary dune in which any structures might be considered to be in danger. However, if a building set back line is to be established, additional factors such as long time erosion, continuity of the dunes, size and shape of the dunes, potential for overwash and other existing features should be considered. This type of information would require a more detailed study than was undertaken in the present report. However, such information can be obtained, and by combining all of this information a reasonable set back line could be established that would provide some guidance for development of our beach front areas.

Acknowledgment

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Table 1. Storm stillwater surge levels and breaking depth of waves for one in a twenty-five, fifty, and one hundred years storm return frequency, respectfully.

	SURGE LEVEL(S) (+Ft.MSL)			BREAKING DEPTH(H_m) (-Ft.MSL)		
	1/25	1/50	1/100	1/25	1/50	1/100
Virginia To Cape Hatteras	7.43	8.20	8.80	7.06	7.79	8.36
Cape Hatteras To Cape Lookout	7.10	7.63	8.00	6.75	7.25	7.60
Cape Lookout To New River Inlet	7.63	9.33	10.95	7.25	8.86	10.40
New River Inlet To Cape Fear	8.80	10.55	12.05	8.36	10.02	11.45
Cape Fear To South Carolina	9.67	11.23	12.45	9.19	10.67	11.83

Table 2. Results of beach recession study for North Carolina Coastline

County and Pier Name	Dune Height (ft. above MSL)	Toe of Dune Height(ft) from MSL	Toe of Dune Dist. from MHW(ft)	Recession from toe of dune (ft) for three storms with specific return frequencies in years		
				1/25	1/50	1/100
Dare County						
Kitty Hawk	19.6	12.1	215	11	34	54
Avalon	18.5	9.3	150	40	70	94
Nags Head	22.9	7.6	112	94	107	126
Outer Banks*	30.0	4.1	75	69	73	78
Hatteras Island	21.7	2.2	102	99	104	108
Cape Hatteras*	24.0	8.8	61	57	66	74
Carteret County						
Triple Ess	22.0	Wall 4.3-9.6	24	91	114	161
Oceana	21.7	5.9	83	101	132	168
Iron Steamer	15.7	6.4	136	80	95	106

*Elevation's assumed and corrected to estimated MWL using N.O.A.A. Tide Tables

Table 2 continued

County and Pier Name	Dune Height (ft. above MSL)	Toe of Dune Height(ft) from MSL	Toe of Dune Dist. from MHW(ft)	Recession from toe of dune (ft) for three storms with specific return frequencies in years 1/25	1/50	1/100
Carteret County						
Emerald Isle*	24.0	6.6	83	66	74	98
Bogue Island*	16.0	8.9	158	21	162	220
Onslow County						
McKee's*	11.0	4.7	78	95	108	134
Paradise	14.1	10.5	173	143	189	223
Ocean City*	12.3	7.0	113	161	206	229
Pender County						
Scotch Bonnet*	23.0	9.4	154	133	144	178

*Elevation's assumed and corrected to estimated MWL using N.O.A.A. Tide Tables

Table 2 continued

County and Pier Name	Dune Height (ft. above MSL)	Toe of Dune Height(ft) from MSL	Toe of Dune Dist. from MHW(ft)	Recession from toe of dune (ft) for three storms with specific return frequencies in years		
				1/25	1/50	1/100
Pender County						
Surf City	25.0	5.6	98	113	186	227
Dolphin	28.3	7.7	114	103	120	188
Ocean	17.9	8.2	103	99	178	234
New Hanover County						
Johnny Mercer	14.0	5.7	112	165	175	180
Crystal*	15.4	6.4	112	123	145	194
Carolina Beach	10.4	Wall (Rock) 4.1-11.3	23	264	347	363
Center	12.9			153	206	270
Kure*	12.8	Wall 12.5-18.5	109	74	124	144

*Elevation's assumed and corrected to estimated MWL using N.O.A.A. Tide Tables

Table 2 continued

County and Pier Name	Dune Height (ft. above MSL)	Toe of Dune Height(ft) from MSL	Toe of Dune Dist. from MHW(ft)	Recession from toe of dune (ft) for three storms with specific return frequencies in years 1/25	1/50	1/100
Brunswick County						
Yaupon*	10.7	2.1	2	175	227	237
Ocean Crest*	12.9	8.0	87	83	101	116
Long Beach	16.7	8.5	105	142	175	192
Holden Beach*	14.9	9.9	157	199	220	265
Ocean Isle*	14.9	None		120	134	150

*Elevation's assumed and corrected to estimated MWL using N.O.A.A. Tide Tables

Table 3. Recommended range of recession lines from the dune toe for one in twenty five and one in a hundred years storm return frequency

	Location	Range of recession lines (ft) 1/25 frequency	1/100 frequency
I	Virginia to Cape Hatteras	40-100	80-120
II	Cape Hatteras to Cape Lookout (one value)	50-100	70-120
III	East-West Portion to Carteret County	70-100	100-170
IV	Onslow County	100-160	130-230
V	Pender County	100-140	180-230
VI	New Hanover County	120-170	180-270
VII	Brunswick County	120-190	150-260

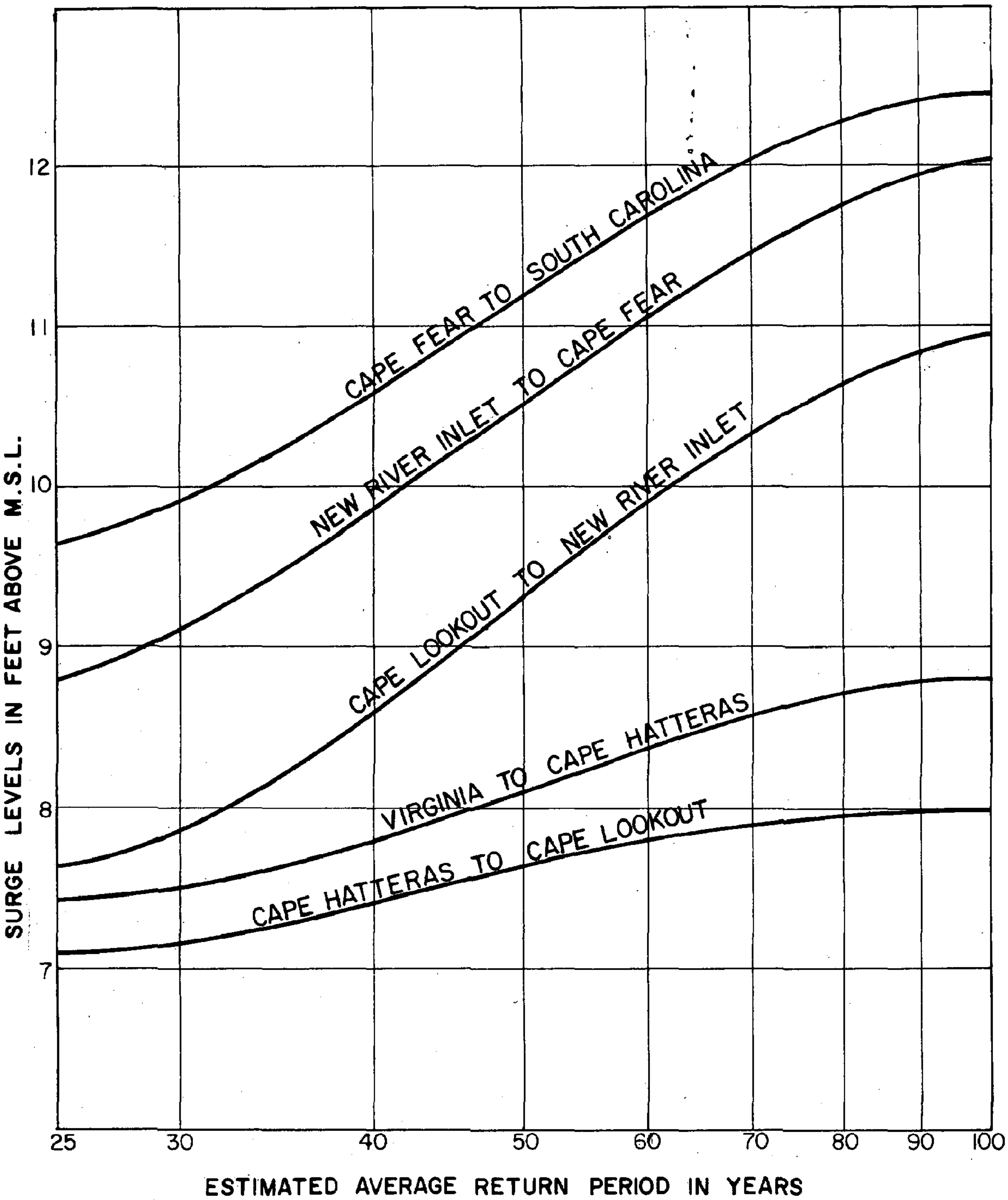

Figure 1. Storm surge levels related to return frequencies for five subdivisions of the North Carolina Coast.

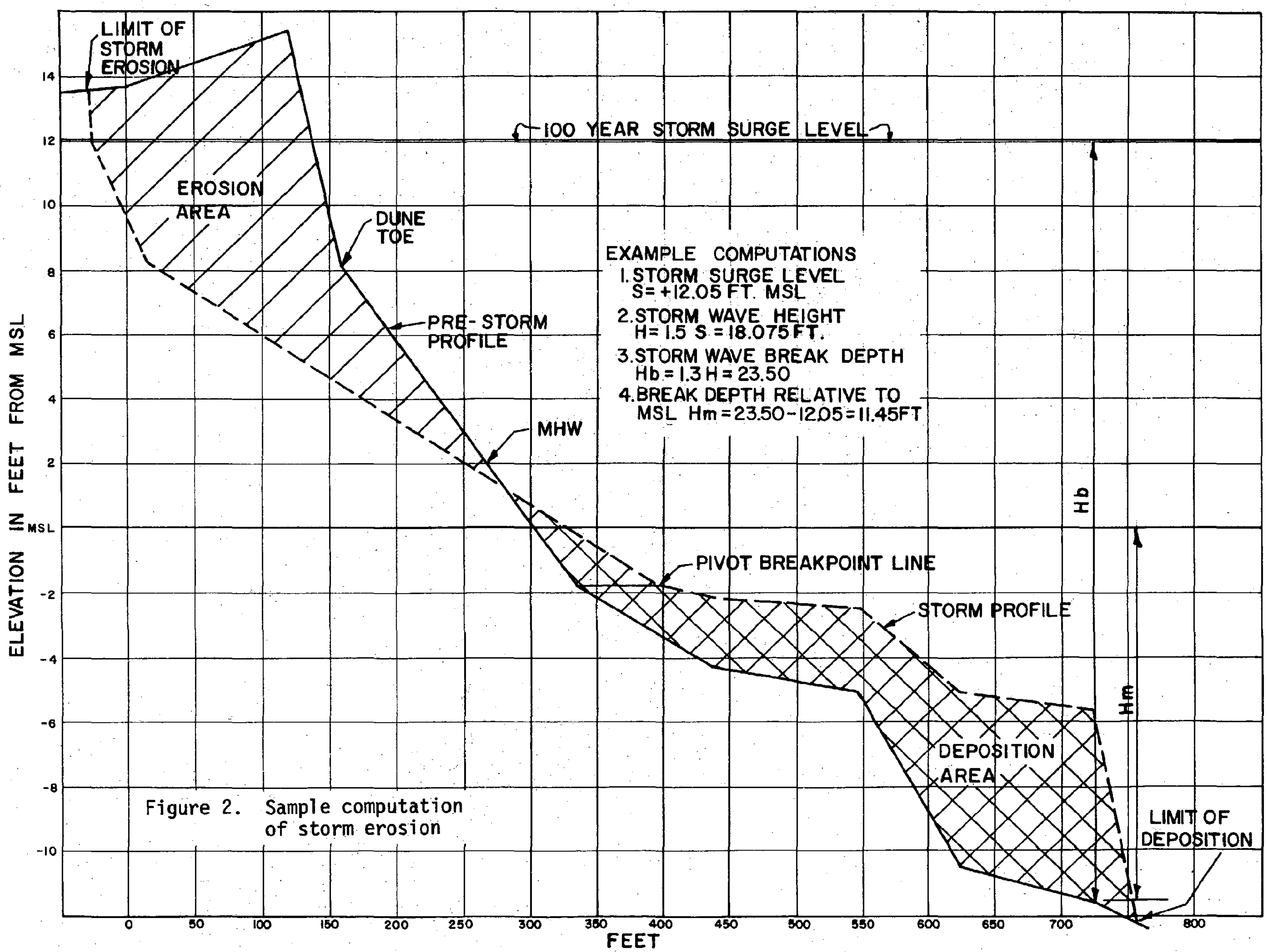

Figure 2. Sample computation of storm erosion

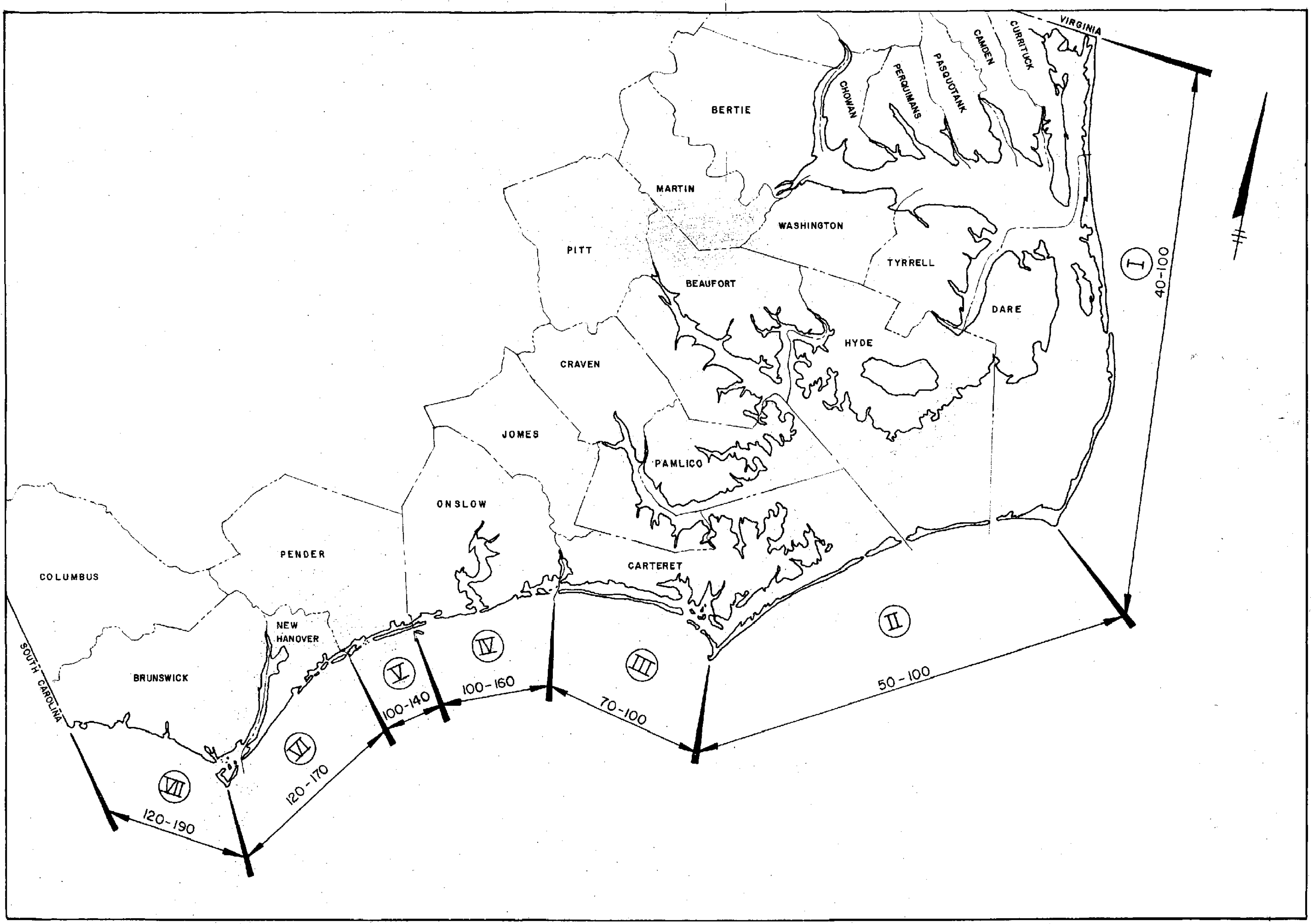

Figure 3. Recommended range of recession lines from the dune toe for one in twenty five years storm return frequency

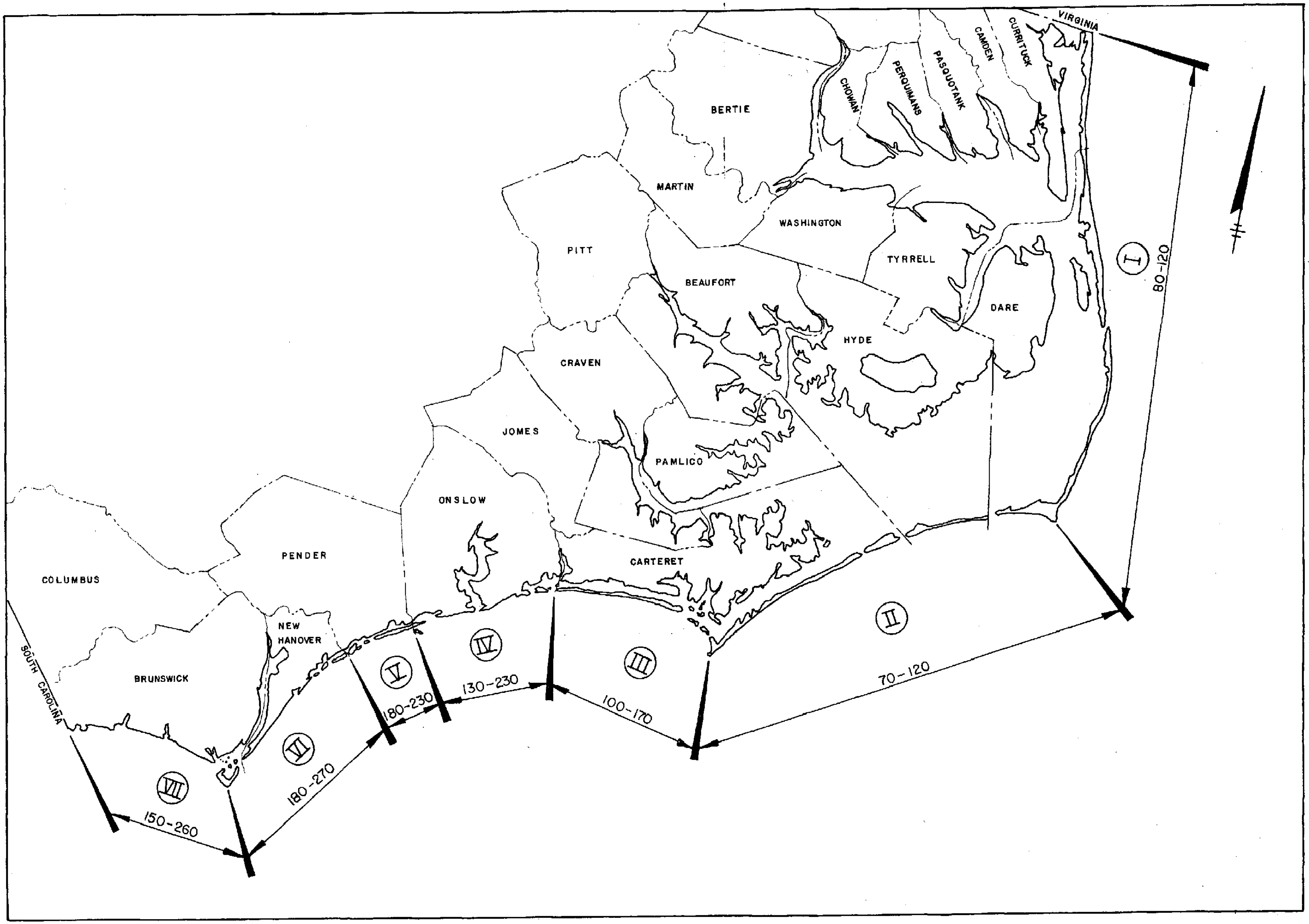

Figure 4. Recommended range of recession lines from the dune toe for one in a hundred years storm return frequency